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TITLE: LOUDSPEAKER

FIELD OF INVENTION

The present invention relates to a loudspeaker, particularly but not exclusively a portable loudspeaker for use with personal CD players (e.g. Sony DISCMAN CD players), personal mini disc players, and personal stereo cassette players (e.g. Sony WALKMAN tape cassette players). For the purposes of the present specification, such CD/mini disc/cassette players are defined as personal players.

BACKGROUND ART

Personal players are primarily intended to produce sound for one listener at a time. For this reason, personal players are supplied with headphones. Nevertheless, portable loudspeakers are available on the market and are intended for occasions when the personal players are used to reproduce sound for more than one person at a time. The portable loudspeakers must be compact and lightweight in order to meet user requirements.

The present applicant has appreciated that existing portable loudspeakers for personal players are perhaps not as compact as the user would like, so much so that storage is sometimes a problem. Therefore, an object of the present invention is to provide a portable loudspeaker which is more readily accepted by the user.

DISCLOSURE OF INVENTION

According to a first aspect of the present invention, there is provided a portable loudspeaker for use with a personal player as hereinbefore defined, comprising a

housing having an outer periphery in the shape of a storage device selected from the group consisting of a CD box, a tape cassette box, and a mini disc box.

CDs, mini discs and audio tape cassettes are traditionally sold in standard-sized storage boxes and, as a result, there is a tendency for the users of personal players to accept readily the size of such storage boxes. Indeed, accessories such as carrying cases for personal players are sometimes designed to accommodate the standard-sized storage boxes in addition to the personal player itself. Accordingly, the present applicant has appreciated that a loudspeaker with a housing of substantially the same dimensions as one of the standard-sized storage boxes (be it single or double or otherwise) is likely to be more readily accepted by users of personal players because its size is in keeping with existing apparatus carried by users.

The housing may comprise an open-top box enclosure and a lid, with the lid being movable from a first position covering the enclosure opening to a second position upstanding from the enclosure. With the lid in the second position, projecting away from the enclosure opening, the interior of the enclosure becomes accessible, possibly for storing an item. The lid may be connected to the open-box enclosure with a hinge.

Preferably, the sound generating unit of the portable loudspeaker is mounted on or in the lid of the portable loudspeaker. In this way, the orientation of the sound-

generating element may be altered by moving the position of the lid relative to the open-box enclosure. This may be useful if the sound generating element produces a directional output, or to take advantage of beneficial reflections of sound waves, e.g. from a flat surface such as a table.

A further sound-generating unit may also be mounted in or on one side of the open-top box enclosure. The said one side may be movable relative to the other sides of the open-box enclosure. In this way, the lid and the said one side may be orientated to face in the same direction, perhaps for stereo sound reproduction, whilst the other sides of the open-box enclosure may project outwards to stabilise the portable loudspeaker. The outer periphery of the portable loudspeaker housing may be in the shape of a double CD, tape cassette or mini disc box, in which the said one side forms the second lid which faces the aforementioned lid when closed.

The dimensions of a CD box, particularly a double CD box, are well suited to producing a portable loudspeaker embodying the present invention.

The sound-generating unit of the portable loudspeaker may comprise a flat panel acoustic radiator and a transducer positioned to excite bending waves in the acoustic radiator and thereby radiate sound energy by flexural vibrations. The flat panel acoustic radiator may be a distributed mode acoustic radiator as disclosed in International patent application published under number

WO97/09842 in the name New Transducers Limited, the whole content of which is incorporated herein by reference. With the distributed mode acoustic radiator, the transducer would be mounted in or on the panel at a preferred location to excite distributed modes of vibration in the panel.

The housing may house a battery for energising the sound generating element of the portable loudspeaker. The housing may also house a radio receiver for receiving radio signal broadcasts and subsequently reproducing sound through the portable loudspeaker. The radio receiver may include an aerial which is embedded in the housing.

According to a second aspect of the present invention, there is provided a portable loudspeaker for use with a personal player as hereinbefore defined, comprising a housing comprising an open-top box enclosure and a lid, a sound generator mounted on or in the lid, and means coupled to the sound generator for receiving output signals from a personal player, wherein the lid is movable from a first position covering the open-top box enclosure to a second position upstanding from the open-top box enclosure.

The receiving means may include a socket for use in combination with a plug electrically connected to the personal player. In another embodiment, the receiving means may comprise: an infra-red receiver for use in combination with an infra-red transmitter coupled to the personal player.

The lid may be connected to the open-top box enclosure with a hinge. A further sound generator element may be

mounted in or on one side of the open-top box enclosure, perhaps facing the enclosure opening. The said one side may be movable relative to the other sides of the enclosure, perhaps pivotally coupled thereto. The outer periphery of the housing may resemble a standard storage device selected from the group consisting of a CD box, a tape cassette box, and a mini disc box. Other features of the second aspect of the invention are as set out hereinbefore with regard to the first aspect of the invention.

According to a third aspect of the present invention, there is provided a loudspeaker comprising an acoustic radiator and a transducer mounted on or in the acoustic radiator to excite bending waves in the acoustic radiator for producing an acoustic output, characterised in that the acoustic radiator comprises a first region and a second region surrounding the first region, the first region being stiffer than the second region and having the transducer mounted on or in it.

The first region may be regarded as a "stiff" island surrounded by the second region which may be regarded as a flexible diaphragm. The first region may have a first uniform stiffness, and the second region may have a second uniform stiffness - the first uniform stiffness being greater than the second. The first and second uniform stiffnesses may be achieved by increasing the thickness of the acoustic radiator across the first region. The first region may be at least 25% thicker than the second region.

The transition between the different thicknesses of the first and second regions may be tapered to avoid a sharp step.

The amplitude of displacements in the acoustic radiator may be greater (perhaps at least five times greater) at frequencies below 300Hz than those at frequencies above 300Hz. Both the first and second regions may be sufficiently stiff to support the propagation of bending waves across the acoustic radiator, at least at high frequencies. However, by providing a peripheral region which is more readily able to flex than the island region, it is believed that the second region may support a degree of pistonic movement in the loudspeaker, thus enabling sound to be produced both pistonically and vibrationally, especially at low frequencies. This may be significant at frequencies up to about 300Hz, where the pistonic contribution to the sound output may provide an important supplement to the vibrational component, especially in compact portable loudspeakers of the present invention.

The portable loudspeakers of either the first or second aspects of the present invention may include as the sound-generating unit a loudspeaker according to the third aspect of the present invention and any specific embodiments.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows schematically a first embodiment of a portable loudspeaker embodying the present invention;

Figure 2 shows schematically a second embodiment of a portable loudspeaker embodying the present invention;

Figure 3 shows schematically a third embodiment of a portable loudspeaker embodying the present invention;

Figure 4 shows lid detail of the portable loudspeaker of Figure 3;

Figure 5 shows a partial cross-sectional view along line XX of Figure 4; and

Figure 6a and 6b shows laservibrometry results illustrating acoustic behaviour at 250 Hz of the portable loudspeaker of Figure 3.

MODES OF CARRYING OUT THE INVENTION

Figure 1 shows a portable loudspeaker (10) resembling a double CD case, and comprising left- and right-hand lids (12,14) pivotally coupled about parallel axes AA and BB to side walling (16). The side walling (16) forms an open box like enclosure, with the left- and right-hand lids (12,14) acting as the top and bottom surfaces to complete the enclosure. The portable loudspeaker (10) is illustrated in the "open" configuration to facilitate a description of the internal components; in the "closed" configuration (not shown), the portable loudspeaker (10) is the same shape and size as a conventional double CD case, and thus has the outward appearance thereof. In the "open" configuration, the side walling (16) acts as a support stand for the portable loudspeaker (10). Rubber feet may be provided on

the bottom surface of side walling (16) to improve grip on smooth surfaces.

Each lid (12,14) comprises a sound generating unit in the form of a distributed mode acoustic radiator (20) mounted in a frame (22) with a compliant foam surround (not shown) sandwiched therebetween to isolate the frame (22) from unwanted vibrations. The acoustic radiator (20) comprises a stiff, lightweight panel (24) and an exciter (26), positioned to excite distributed mode bending waves in the panel (24). The acoustic radiator (20) works in accordance with the teachings of the disclosure of WO97/09842, the whole contents of which are incorporated herein by reference, and accordingly further explanation is unnecessary. The exciter (26) in the left-hand lid (12) is offset relative to the one in the right-hand lid (14) to avoid fouling when the portable loudspeaker (10) is in the closed configuration.

The side walling (16) acts as a spacer between the left- and right-hand lids (12,14), providing storage space for certain components. An amplifier (30) including a volume control (32) is mounted towards one corner of the side walling (16). The amplifier (30) is coupled to input connector (34) for receiving an output setting from a personal player such as a personal cassette player (36). The input connector (34) could be replaced with a receiver for receiving infra-red output signals from a transmitter coupled to the personal player. The amplifier (30) sends electrical signals to the exciters (26) via wiring (not

shown) in order to generate sound. A battery (40) supplying power for the amplifier (30) is located in the corner of the side walling (16) opposite the amplifier (30); by locating the amplifier (30) and battery (40) in opposing corners, space is left available to accommodate the exciters (26) when the loudspeaker (10) is in the closed configuration. A 12 volt d.c. input socket may be provided so that power may be introduced from a mains supply (*via* a transformer) as an alternative to the battery (40).

The amplifier (30) has incorporated with it a radio receiver (38) for receiving radio wave broadcasts to enable radio broadcasts to be heard using the portable loudspeaker (10). The radio receiver (38) has an aerial (39) embedded in side walling (16). An MP3 or mini-disc player may also be incorporated in the assembly, perhaps alongside the amplifier.

Despite the presence of compliant foam isolating the acoustic radiator (20) from the frame (22), some vibrations may still be conveyed through the frame to the side walling (16). Vibrations induced in the side walling (16) may be undesirable, and may be reduced by placing compliant foam absorbers (not shown) where the frames (22) may otherwise be in contact with the side walling (16).

Figure 2 shows a portable loudspeaker (50) resembling a single CD case, and comprising a lid (52) pivotally coupled about axis A^1A^1 to open-top box enclosure (54). Open-top box enclosure (54) consists of sides (56) with an acoustic radiator (24, 26) coupled thereto. The portable

loudspeaker (50) is illustrated in the "open" configuration to show the internal components.

Where there are features in common with the embodiment of Figure 1, the same reference numerals have been used. A slimline battery arrangement (58) is illustrated, and the amplifier omitted for convenience. In any event, a miniature digital amplifier could be used in place of the somewhat larger analogue amplifier illustrated in Figure 1. A key difference between the Figure 1 and 2 embodiments is the fact that there is no independent side walling so that the lid (52) is hinged direct to the sides (56) defining with a base the open-top box enclosure (54). The acoustic radiator (24, 26) in the open-top box enclosure (56) is optional and if only one acoustic radiator is required in the portable loudspeaker (50), a standard panel (60) would be used as the base of the enclosure. A stereo signal could still be reproduced by using a pair of such loudspeakers.

Figure 3 shows a portable loudspeaker (70) resembling a double CD case. Where there are features in common with the embodiment of Figure 1, the same reference numerals have been used. Each lid (12,14) comprises a sound-generating unit comprising an acoustic radiator (72) which comprises a two-region panel (74) and an exciter (76), positioned to excite bending waves in the acoustic radiator for producing sound. Each acoustic radiator is integrally formed with the respective lid, being moulded from polycarbonate. Thus, there is no compliant foam isolating the acoustic radiator from the rest of the lid.

Figures 4 and 5 shows detail of lid (14) - including the position (78) for the corresponding transducer (equivalent to that of lid (12) when rotated through 180°). The position (78) may not be the optimised position for locating the transducer. The two-region panel (74) comprises a first region (80) of thickness t_1, and a second region (82) of thickness t_2. The second region (82) surrounds the first region (80) which may thus be regarded as an "island". The two-regional panel (74) is such that $t_1 > t_2$, and in the present case t_1, is 2.0mm and t_2 is 1.2mm. This means that the first region (80) is stiffer than the second region (84).

In use, a transducer (76) positioned on site (78) will produce bending waves across the panel (74). The first region (80) - being relatively stiff and lightweight - is particularly suited to propagating such bending waves. At frequencies below 300 Hz - say 250 Hz - the second region (82) allows for some pistonic movement in a direction perpendicular to the panel surface by virtue of the fact that it is less stiff than the first region (80).

Figures 6a and 6b are based on stills taken from laservibrometry experiments at an operating frequency of 250 Hz and give amplitude plots at two phases, 180° apart. On the left hand side of each Figure, results are shown for the two-region panel (74) of Figure 4 with the amplitude readings taken along a line passing through an exciter. For comparison, on the right hand side of each Figure, results are plotted for an equivalent uniform (distributed mode)

panel made from polycarbonate sheet 2mm thick. The amplitude displacements are greatest for the two-region panel (74) where the transducer/exciter (76) is located; the maximum amplitude is perhaps seven times or more greater than that of conventional panel provided for comparison. The increased, pistonic-type displacements at frequencies below about 300Hz provide an enhanced bass response.